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(58) Field of search
G3N
G3R

(54) **Controlling temperature in large buildings**

(57) Controlling temperature in a large building in accordance with a time and temperature demand programme which is modified by meteorological forecast data to attain the demanded time and temperature programme whilst minimising energy input to thermal plant for the building. The times at which central heating is switched on and off may be determined in dependence on the forecast. Different zones in the building (or in seperate buildings) may be separately controlled by a common computer.

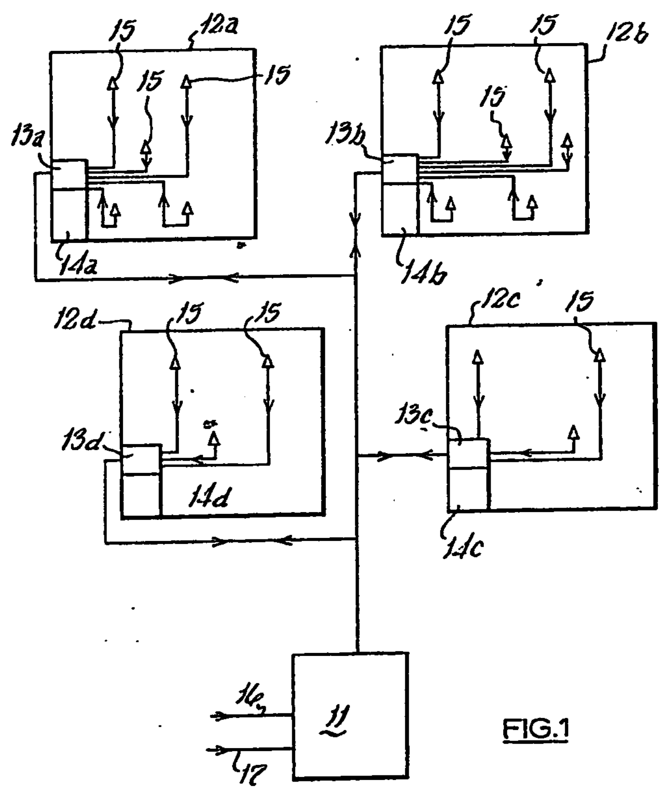

FIG.1

The drawings riginally filed were informal and the print here repr duced is taken from a later filed formal copy.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patent Rules 1982.

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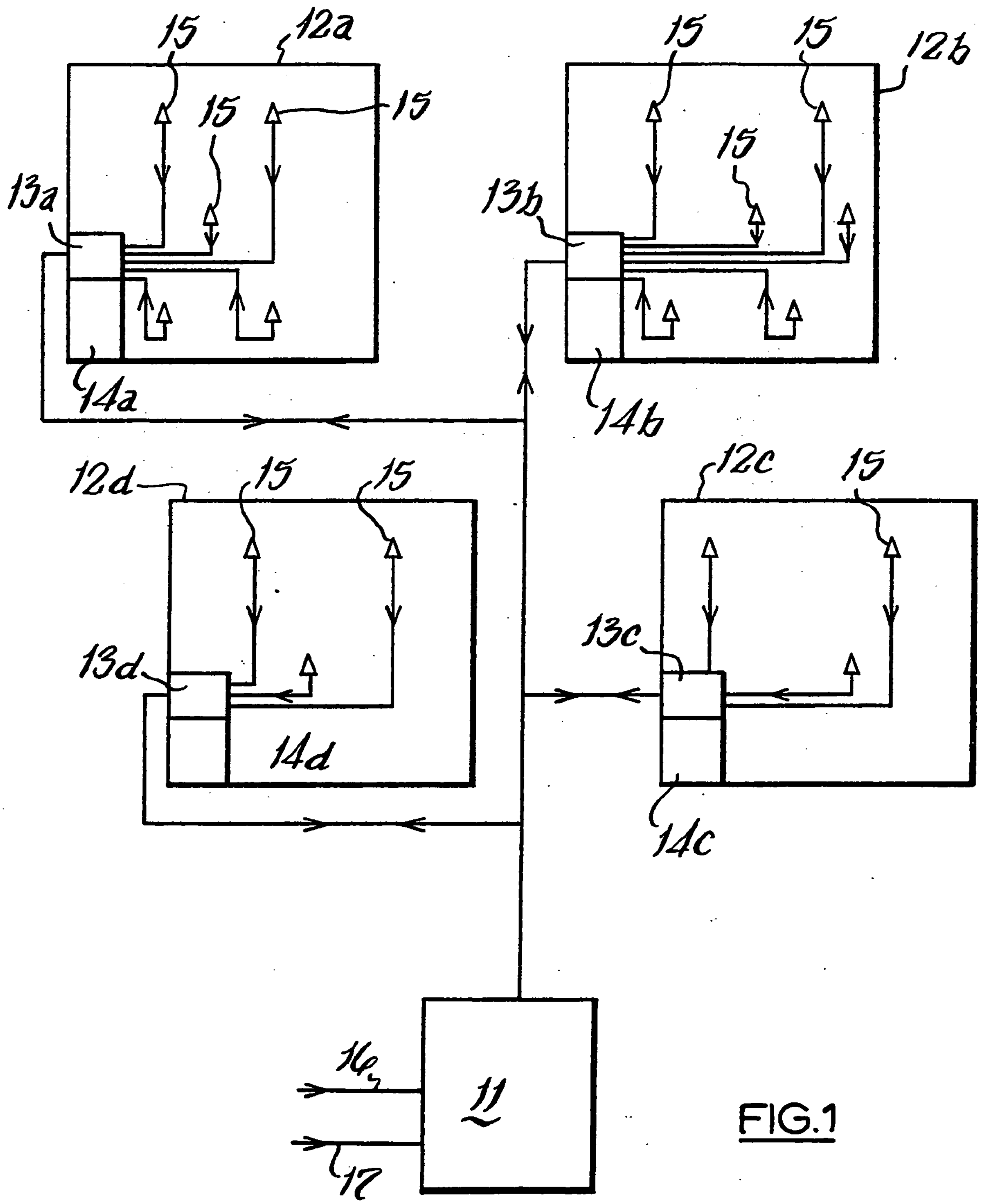
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12a
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13b
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13d
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15
13c
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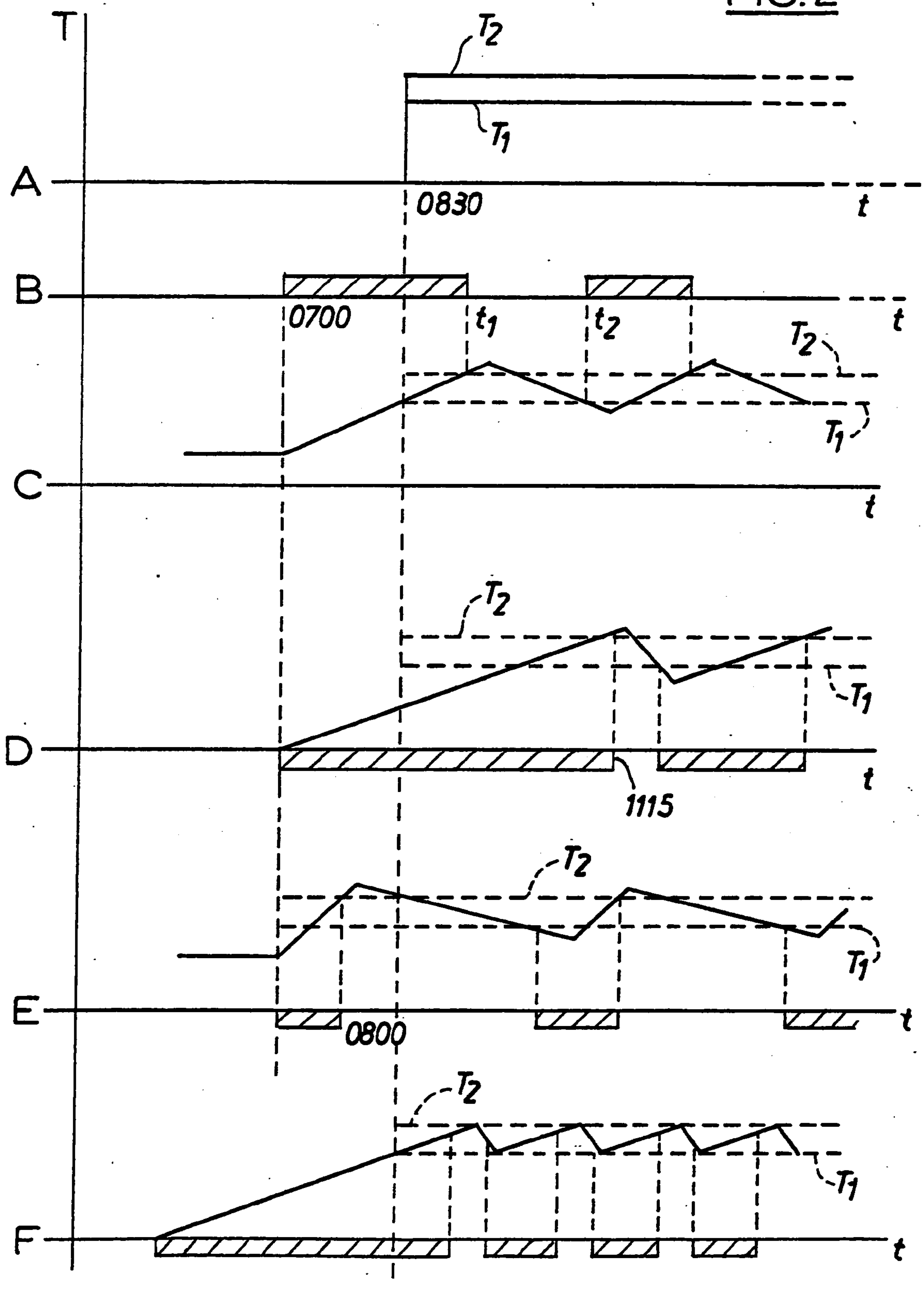
16
11
17

FIG.1

FIG. 2



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SPECIFICATION

Controlling temperatur in large buildings

This invention relates to controlling temperature in large buildings, such as office buildings, apartment blocks, department stores, theatres and concert halls and factories.

Conventionally, such buildings are heated by central heating and/or cooled by a chiller of an air conditioning system, which may be under some form of time control or which may be operated manually, and which may further be subject to some form of temperature control whereby the heater or chiller, though in an "on period", are switched off by a thermostat on the temperature reaching a predetermined level.

For an office block, say, which is required to be at a comfortable temperature between the hours of 9am and 5.30pm, it is necessary, of course, to operate the heater or chiller some time ahead in order to bring the temperature to that required by 9am; likewise, it is possible to switch off the heater or chiller before 5.30pm. The times at which the heater or chiller is switched on and off will be determined by a trial. When - as usual - a timer is provided, it will be set to operate the heater or chiller at the times determined by the trial.

In particular cold weather, however, the heater may not bring the temperature up to the required temperature by 9am and, likewise, the building may cool down rapidly so as to be uncomfortably cold between the time the heater is switched off and 5.30pm. It is possible of course to override the time control manually, and the building's engineer will be able to switch the heater on earlier in very cold weather and let it run on longer in the afternoon.

Depending, however, as it does on a mixture of guesswork and experience, and relying on manual intervention, this practice is unreliable both as a method of ensuring the desired temperature/time relationship in the building and also as a method for optimising fuel or power consumption. Matters can be improved somewhat by connecting an outdoor thermometer to a time control arrangement so as to switch the heater or chiller on earlier if the outdoor temperature is lower and later if it is higher than a given temperature. However, the relationship between outdoor temperature and time to reach a given indoor temperature may be quite complicated, so that this still does not ensure a desired temperature/time relationship coupled with minimising fuel or power consumption. Moreover, in the case of a large building, which requires two or three hours heating to bring it up to temperature, the outdoor temperature is quite likely to change during the warm up period.

Further complications arise if different parts f the building are required to be heated to different temperatures or for different time periods, or if parts of the building contain variable heat inputs. Wind strength and dir ction can also influenc th rate of loss of heat from a building.

By the present invention, improved control of the heater or chiller can be achieved eliminating the guesswork and taking into account more factors influencing the temperature in a building and the consumption of fuel or power.

The invention comprises a method for controlling temperature in a large building, in which a thermal plant is automatically controlled according to a time and temperature demand program and in accordance with meteorological data in such manner as to tend to compensate for anticipated ambient conditions to attain the demand time and temperature program and to minimise energy input to said heater or chiller in so doing.

By "thermal plant" is meant any arrangement used for heating or cooling a building including oil or gas fired circulated water heating arrangements, air conditioning arrangements, storage heater arrangements and solar energy arrangements.

The effect of the meteorological data may comprise controlling the time during which the thermal plant is operative.

The manner in which meteorological data are applied may be based on observation of the results of previous application of such data in connection with the control of temperature in said building.

The time and temperature demand program may demand a desired temperature during a first period and an uncontrolled temperature during a second period and the meteorological data may then be applied in such manner as to operate the thermal plant at the latest time before said first period and to turn off the thermal plant at the earliest time before said second period consistent with said desired temperature being maintained throughout said first period.

The control may be effected by a microprocessor, computer or like device.

Temperature may be controlled in a plurality of locations by a common control arrangement. Such locations may comprise different parts of a building and/or different buildings. A single computer located in one building may control that building and several others in the same district.

The various locations controlled may have temperature measuring means supplying temperature date to the common control arrangement. Such temperature information may be used to determine the effectiveness of the control of the thermal plant whereby the manner in which meteorological data are applied can be modified if necessary to produce improved results.

The meteorological data may include temperature data over a forecast period and may comprise an average temperature over such period or expected values of temperature at intervals during said period. The data may also include wind data.

The invention also comprises apparatus for controlling a thermal plant for contr lling temperature in a large building comprising program means presettable to demand a given time and temperature program and control means comprising input means for meteorological data and adapted to contr l said thermal plant using said data to achieve said giv n program compensating for ambient conditions and minimising energy input to the

thermal plant in so doing.

A common computer may be used as said control means for controlling temperature in a plurality of locations - such as separate buildings - each such location having a local microprocessor connected to said common computer, the microprocessor containing said preset time and temperature program and communicating temperature information to said common computer.

The common computer can thus handle the meteorological data input for each of the microprocessors and use the temperature information to control the thermal plant at each location to take into account the different thermal properties of the locations. In this way, the thermal properties are taken into account without it being necessary to measure them explicitly - the temperature information is in a sense fed back to the computer which then modifies the operation of the thermal plant in accordance with actual and anticipated ambient temperature and other factors such as wind data if desired to achieve the preset time and temperature program with the most efficient utilisation of fuel or power.

One embodiment of apparatus and a method for controlling temperature in large buildings according to the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a block diagram of control apparatus serving four buildings, and

Figure 2 is a series of graphs showing the demand on, and the operation and effect of a thermal plant according to the invention.

The apparatus illustrated in Figure 1 comprises a common computer 11 controlling four buildings 12a, 12b, 12c and 12d. Each building has its own microprocessor 13a, 13b, 13c, 13d controlling thermal plant 14a, 14b, 14c, 14d which may comprise a gas or coil fired boiler for a hot water control heating system, or a burner for a hot air system or a chiller for an air conditioning system.

The microprocessor 13a - 13d are connected to the computer 11 so as both to receive command signals therefrom and to send data thereto.

Temperature measuring devices 15 are situated in each building 12a - 12d and connected to the microprocessors 13a - 13d, which feed back temperature information to the computer 11.

The computer 11 has a direct input 16 of current local meteorological data, which comprise essentially temperature and which may additionally comprise wind data, relative humidity and any other factor found to have any significant effect on the thermal behaviour of the buildings 12a - 12d. It may be found, for example, that one of the buildings is unduly affected by a cold north-easterly wind, while oth rs may be mor sheltered and not significantly affected. The direct input may be from a measuring device or a collection of measuring devices up to a full meteorological station. If the buildings 12a - 12d are widely scattered, it may be preferred to monitor current meteorological conditions locally to the building and feed the data to the computer 11 either direct or *via* the microprocessor 13a - 13d.

The computer 11 also has an input 17 - which may be a conventional keyboard - for meteorological forecast data. Such data can be received by telephone, for example, and keyed in at regular intervals. It would however also be possible to connect the computer 11 directly to a meteorological bureau so as to receive forecast data automatically.

Figure 2 illustrates the manner of operation of the arrangement shown in Figure 1, looking specifically at the situation for one of the buildings 12a - 12d.

The figure comprises a number of graphs of temperatures T against time t and duty cycles of a boiler of a central heating system of the building and show the situation for a typical office building in the morning. Graph A shows the demand program, which is simply that at time t = 0830 hrs the temperature has to be between lower and upper limits T_1 and T_2, say 20°C and 22.5°C. Graph B shows a typical duty cycle for a clock and thermostat controlled system, and graph C shows the effect. The system starts up to 0700 hrs - and hour and a half in advance of the time the building is required to be up to 20°C. The system is switched off at time t_1, some time after 0830 hrs when the temperature has reached T_2. The building temperature now falls to T_1 at time t_2, when the system is switched on again. This continues throughout the day until the system is switched off by the clock. It is usual to switch off the system ahead of the time the building closes, just as it is switched on ahead of the building opening.

It will be noticed from graph C that in fact the temperature does not begin to fall immediately the boiler is switched off - there is always a delay before a change in the boiler state has an effect on the temperature of the building. This results in the temperature actually exceeding T_2 and falling below T_1 from time to time, which is both inefficient and occasionally uncomfortable.

Graph D - which also shows the boiler duty cycle - shows what happens in colder weather with such a simple system. The boiler starts up to 0700 hours as before, but the building is colder. Not only does the temperature have to be raised through a greater extent, but also the rate of loss of heat from the building is greater and thus the rate of temperature increase is slower. The temperature may not reach the minimum comfort level T_1 until, say, 1115 hrs.

On the other hand, when the weather is warmer as shown in graph E (and duty cycle), the temperature reaches T_1 by, say, 0800 hrs and may even exceed T_2 before 0830 so that the building is wastefully heated during a time when there is nobody present.

Graph F shows the duty cycle and temperature for colder weather as improved according to the invention. The meteorological data input to the computer 11 cause the boiler to fire earlier at t_0 in order to allow more time for the building to r ach T_1 by 0830 hrs. The time t_0 is, when the system is first installed, determined by a rule based on a mathematical mod l of the thermal behaviour of the buildings. Each building 12a - 12d may initially

have the same mathematical mod l, or they could have different mathematical models if this seems appropriate. A typical mathematical model might specify, for example, that if the external temperature is constant at T_0 the boiler will heat the building at a rate of K_1 $(K_2 + T_0)$ degrees per hour, where K_1 and K_2 are constants which can be set initially by experience or guess work. The initial setting may well be wrong. However, the feed back of temperature information from the temperature measuring devices 15 will enable the computer 11 to calculate better values for K_1 or K_2 or both.

Moreover, the external temperature need not be assumed to be constant at T_0 - from forecast data, a better switch-on time may be had by taking T_0 as the expected average temperature between a given, arbitraily early time and the time at which temperature T_1 is required.

Even better would be to "sample" the forecast temperature data at intervals and integrate the temperature function backwards from T_1 to find the total heat input required and divide this by the boiler output to calculate a switch-on time.

Applying any of these principles during the period when the temperature is required to lie in the range T_1 to T_2 will also reduce or eliminate the tendency to overshoot the maximum and minimum temperatures because of the inertia of the system, and will tend to ensure that the eventual switch-off time is as early as possible consistent with the temperature remaining at or above T_1 for the period demanded.

This deals only with the relatively simple case of the influence of external temperature and temperature trends on the firing of the boiler. Other factors such as wind speed and direction, both present and forecast, can also be taken into account in more sophisticated mathematical models of the thermal behaviour of the building.

Moreover, a greater degree of control can be given to the computer 11 and/or the microprocessors 13a - 13d than merely switching on and off the boiler or other thermal plant. The equipment can also be used to control the distribution of the heat raised by the thermal plant. A building might for example, have a south facing and a north facing side, of which the south facing side receives much more heat than the north facing side when the sun is shining. Control of radiator valves may be given to the computer or microprocessor so that radiators on the south facing side of the building can be shut down, or at least the flow in them restricted in response to sunshine.

The different buildings will probably have quite different thermal characteristics and require different mathematical models. The models may be in the form of mathematical functions as suggested above, but on a scale of sophistication which may be as complex as desired, or they may be simply tables of numbers assembled from historic data which can be "looked-up" whenever a given situation arises.

CLAIMS

1. A method for controlling temperature in a large building, in which a thermal plant is automatically controlled according to a time and temperature demand program and in accordance with meteorological data in such manner as to tend to compensate for anticipated ambient conditions to attain the demanded time and temperature program and to minimise energy input to said thermal plant in so doing.

2. A method according to claim 1, in which the effect of the meteorological forecast data comprises controlling the time during which said thermal plant is operative.

3. A method according to claim 1 or claim 2, in which the manner in which meteorological forecast data are applied is based on observations of the results of previous application of such data in connection with the control of temperature in said building.

4. A method according to claim 3, in which the time and temperature demand program demands a desired temperature during a first period and an uncontrolled temperature during a second period and the meteorological data are applied in such manner as to operate the thermal plant at the latest time before said first period and to turn off the thermal plant at the earliest time before said second period consistent with said desired temperature being maintained throughout said first period.

5. A method according to any one of claims 1 to 4, said control being effected by a microprocessor, computer or like device.

6. A method according to any one of claims 1 to 5, in which temperature is controlled in a plurality of locations by a common control arrangement.

7. A method according to claim 6, in which said plurality of locations comprise different parts of a building.

8. A method according to claim 6 or claim 7, in which said plurality of locations comprise different buildings.

9. A method according to any one of claims 6 to 8, in which said common control arrangement is situated remote from at least one of said locations.

10. A method according to any one of claims 6 to 9, said locations having temperature measuring means supplying temperature data to said common control arrangement.

11. A method according to claim 10, said temperature information being used to determine the effectiveness of the control of the thermal plant whereby the manner in which meteorological forecast data are applied can be modified if necessary to produce improved results.

12. A meth d according to claim 11, the manner in which meteorological forecast data are supplied being modified automatically in accordance with said temperature data whereby to improve the effectiveness of the control of the thermal plant.

13. A method according to any one of claims 1 to 12, in which said meteorological forecast data comprise temperature data for the forecast period.

14. A method according to claim 13, in which said temperature data comprise an average temperature for said forecast period.

15. A method according to claim 13 r claim 14, in which said meteorological forecast data comprise wind data.

16. A method substantially as hereinbefore described with reference to the accompanying drawings.

17. Apparatus for controlling a thermal plant for controlling temperature in a large building comprising program means presettable to demand a given time and temperature program and control means comprising input means for meteorological forecast data and adapted to control said thermal plant using said data to achieve said given program compensating for ambient conditions and minimising energy input to the thermal plant in so doing.

18. Apparatus according to claim 17, said program means comprising a microprocessor.

19. Apparatus according to claim 17 or claim 18, for controlling temperature in a plurality of locations said control means comprising a common computer having said input means for meteorological forecast data.

20. Apparatus according to claim 19, said plurality of locations being comprised in different buildings, each building having microprocessor program means and each such program means being connected to said common computer.

21. Apparatus according to claim 19 or claim 20, each said location having temperature measuring means supplying temperature data to said computer.

22. Apparatus for controlling temperature in a large building substantially as hereinbefore described with reference to the accompanying drawings.

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